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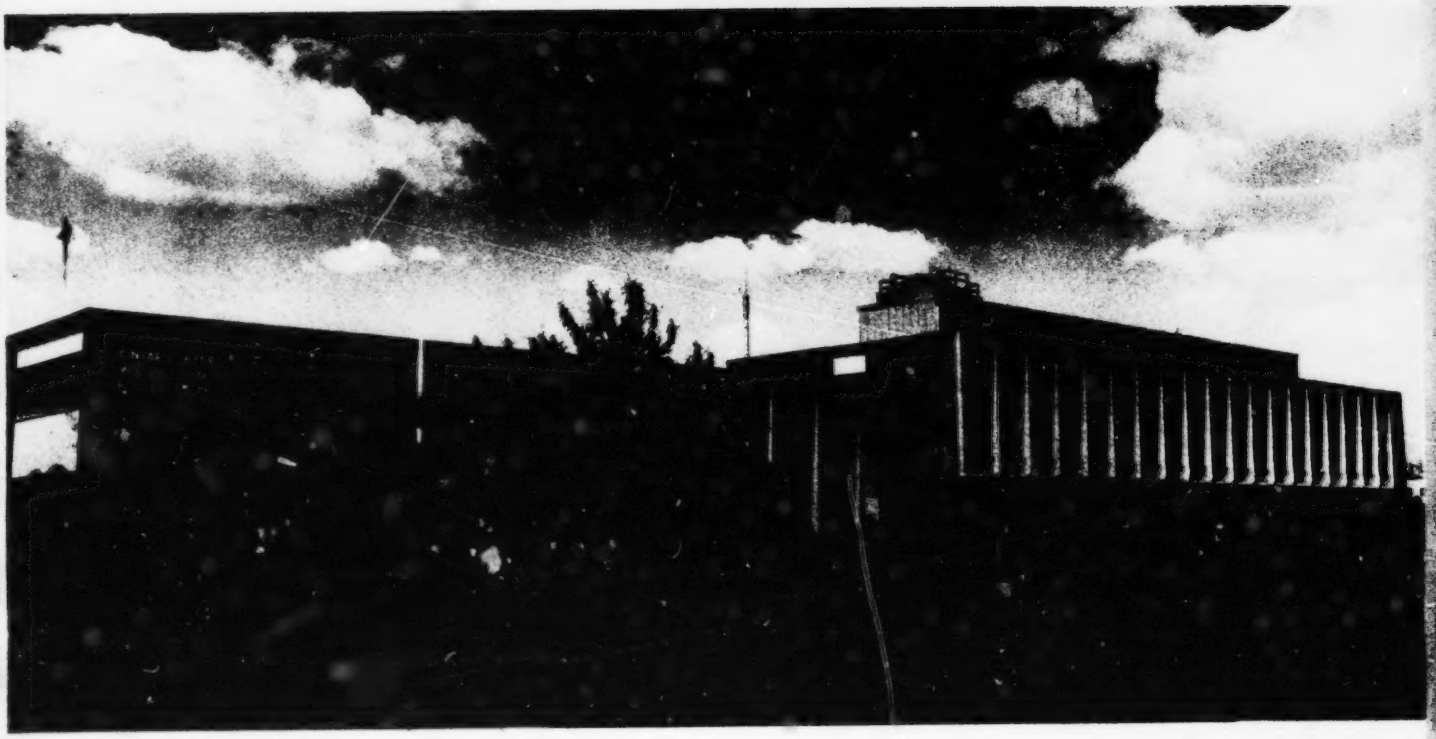

Named in honour of Dr. W.P. Dobson, the Research Division's director from 1914 to 1953, the building shown on the front cover was first occupied in 1961. Along with the adjacent pump testing complex and the high-voltage, high-current and radioactive materials laboratories, it accommodates much of the research, development and testing work performed in support of the diverse technical needs of Ontario Hydro.

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AN ASSESSMENT OF THE NEED FOR ONTARIO HYDRO'S ACID RAIN MONITORING NETWORK

Report No 83-264-K

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EXECUTIVE SUMMARY

Concern over the health effects of sulfate aerosols led Ontario Hydro to set up a sulfate aerosol monitoring network in southern Ontario in 1975 at the urging of the Environmental Coordinating Committee for Air (ECC-A). This network was later expanded and revamped to allow monitoring of acid rain. Important conclusions regarding sulfate aerosol and acidic deposition have been arrived at on the basis of the data collected.

This monitoring program was discussed at the January, 1983 ECC-A meeting at which time it was decided that Ontario Hydro's continuing requirements for acid rain data, the ongoing monitoring activities of other agencies and the degree to which our requirements are met by these monitoring activities be evaluated in more detail by representatives of Design and Development, Research and Thermal Generation Divisions. This report includes the findings and conclusions as modified with input from ECC-A.

An ongoing requirement to determine the contribution of Ontario Hydro's acidic gas emissions to acidic deposition in Ontario and neighbouring regions was identified. This generally requires the use of models which must be developed and verified through the use of air and precipitation monitoring data. An adequate number

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of wet deposition monitoring stations are operated in Ontario and neighbouring regions by other agencies.

Measured concentrations of pollutants in air are used to estimate dry deposition by multiplying by an appropriately selected deposition velocity. The same approach is used in long range transport models to arrive at dry deposition from calculated air concentrations. Measured concentrations in air are thus as valuable as wet deposition measurements in developing and verifying models. Unfortunately, concentrations of acidic species in air are being measured at a relatively small number of sites, mainly in Ontario. In spite of this concern for the poor coverage of the air concentration field, the working group concluded that Ontario Hydro's needs for acid rain data can be met reasonably well by data from other agencies.

Two other requirements were identified. Firstly, it is important to maintain technical expertise for dealings with regulatory and other agencies on issues such as export licence applications and, secondly, the public will continue to view Ontario Hydro as a significant emitter of acidic gases and expect that we contribute to the study (as well as control) of acid rain. It was observed that an imbalance exists in scientific effort, favouring monitoring over data interpretation. Application of our efforts toward data analysis offers a means of maintaining technical expertise while contributing to the study of acid rain in a meaningful way.

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To Mr. F.J. Kee
Director of Research

AN ASSESSMENT OF THE NEED FOR ONTARIO HYDRO'S ACID RAIN MONITORING NETWORK

1.0 INTRODUCTION

The publication of the Community Health and Environmental Surveillance System (CHESS) report by the US Environmental Protection Agency (EPA) in 1974 caused significant concern to the utility industry in North America. This report claimed that the health effects originally attributed to exposure to SO_2 were, in fact, due to a new pollutant, sulfate aerosol, and that the threshold values for sulfate effects were much lower than for SO_2. Utility industry emissions of SO_2 were implicated in the formation of sulfate through the processes of long range transport and chemical transformation.

These claims led to immediate reaction on the part of the utility industry. Independent analyses of the CHESS data were initiated. As well, major studies of prevailing sulfate concentrations and sulfate formation mechanisms were started.

At Ontario Hydro, the Environmental Coordinating Committee - Air sensed the importance of the sulfate issue early on and requested that an assessment and proposal for work be prepared by Research Division. A proposal was completed at the start of 1975. Following discussion of this document, a modest sulfate monitoring network was established in southern Ontario in the summer of 1975. Four precipitation samplers were added to the network in 1976.

The properties of sulfate aerosol had become evident by 1978. In particular, it was apparent that this was a regional pollutant exhibiting similar concentrations throughout southern Ontario on any particular day. This led to the decision in 1978 to expand the network to the southwest and north in order to obtain better geographical coverage of concentrations, both on an annual and a short-term or episode basis.

The main findings of the work done between 1975 and 1980 may be summarized as follows:

- Important properties of sulfate aerosol were determined, these include the existence of

  - a large day-to-day variability in concentrations
  - similar concentrations over large regions on any one day
  - a concentration gradient in a south-north direction with values decreasing towards the north,

- Long range transport of sulfate aerosol takes place on occasion,
- High sulfate aerosol concentrations are associated with poor visibility, and
- Some properties of wet acidic deposition were determined; these include the existence of
  - large episode-to-episode and smaller seasonal variability in composition
  - sulfur and nitrogen acids as the main acidifying species
  - a concentration gradient in a south-north direction with acidity and ionic composition decreasing towards the north

The claims made in the CHESS report about the health effects of sulfate aerosol did not stand up to scrutiny. In the meantime, however, acid rain surfaced as a serious environmental concern in North America. It was decided, therefore, to revamp the sulfate survey into an acid rain survey in 1980. The changes and the reasons behind them were discussed at an ECC-A meeting where it was stated that:

- Emphasis was being shifted to acid rain monitoring; this required measurement of the most relevant acidic species in wet and dry forms,
- The quality of the data was to be improved by upgrading the equipment and analytical techniques and by relocating the six stations to regionally representative sites, and
- A data set was to be collected so that the following could be investigated
  - ratio of wet-to-dry acidic deposition
  - relationship between air and precipitation concentrations
  - importance of sulfur and nitrogen acids in summer and winter
  - influence of transport direction, synoptic situation, etc on precipitation composition

This data collection effort is scheduled to end on May 31, 1983. Data interpretation and analysis required to satisfy the stated goals of the project will then follow.

The sulfate/acid rain monitoring program was reviewed again at the January, 1983 ECC-A meeting. At that time it was decided that a working group with membership from Design and Development, Research and Thermal Generation Divisions be constituted to:

- Consider Ontario Hydro's requirements for acid rain data,
- Review monitoring activities going on elsewhere,
- Assess how well the monitoring activities going on elsewhere satisfy Ontario Hydro's continuing requirements for acid rain data, and
- Make recommendations to ECC-A on what to do with the monitoring network.

The working group investigated these issues and prepared a draft report on the findings and conclusions which was distributed to ECC-A members and discussed at the April, 1983 ECC-A meeting. This final report includes the findings and conclusions of the working group as modified with input from ECC-A.

2.0 ONTARIO HYDRO'S REQUIREMENTS FOR ACID RAIN DATA

Ontario Hydro's main requirement with regard to acid rain is to know the contribution of its emissions to acidic deposition in Ontario and neighbouring regions. This knowledge is needed in dealings with regulatory agencies and the general public. Regulatory agencies wish to ensure that Ontario Hydro's operations lead to acceptable environmental impact, while the public expect Ontario Hydro to contribute to the understanding and solution of the acid rain problem.

Acid rain data are essential in satisfying the above requirement. This will be discussed below under the headings of:

- Contribution to acidic deposition, and
- Dealings with regulatory agencies and the general public.

2.1 Contribution to Acidic Deposition

Ontario Hydro operates large thermal generating stations which emit significant amounts of acidic gases (SO_2 + NO_x). The magnitude of these emissions, however, is decreasing rapidly from the estimated 500,000 Mg/a in 1983 to about 180,000 Mg/a in 1988.

As a significant emitter of acidic gases, Ontario Hydro needs to know the contribution of these emissions to acidic deposition in Ontario and neighbouring regions. At first glance, we might consider determining this contribution through measurements, calculation or some other means. In practice, it turns out that the contribution of individual sources, even the larger ones, is small and nearly impossible to measure directly unless the source is remotely located. As a result, calculations involving the use of long range transport models have had to be performed to estimate contributions. This method is likely to remain the only viable approach in the foreseeable future.

Acid rain data are essential in long range transport modelling. First of all, the data are used to determine the important properties (seasonality, geographical gradients, episodicity, important ionic species, effect of meteorology, etc) that must be reproduced by the models. Secondly, the data can be used to estimate model parameters and finally, acid rain data are needed to test the accuracy of the models. Over the long term, it will also be possible to relate changes in acid rain directly to changes in emissions.

Existing models are rather crude and work best when applied in situations requiring long averaging time predictions. Acid rain data of comparable averaging time (monthly is common) are sufficient for applications involving these models. However, as more sophisticated models are developed, modelling of episodes will become possible and more detailed, event-type, acid rain data will be required.

In summary, then, long range transport models will likely provide the only viable option to estimate Ontario Hydro's contribution to acidic deposition over the foreseeable future. These models are crude but will be improved with time. Acid rain data are needed so that the properties of this pollutant may be determined and the models designed in such a way that these properties are predicted. Data are also required to estimate model parameters and to compare against model predictions. Some applications require data with a long averaging time, others must be based on event-type data. The trend in the future will be toward event-type data. Both air and precipitation chemistry data are required in order to properly test the accuracy of long range transport models.

2.2 Dealings with Regulatory Agencies and the General Public

Ontario Hydro deals with regulatory agencies such as the Ontario Ministry of the Environment, Environment Canada and the National Energy Board. Acid rain and acid gas emission controls have been the focus of much of the recent dealings. Such discussions reached a climax when the Province imposed emission limits on Ontario Hydro. Discussions have taken place in connection with applications for export licences and are expected to continue for some time yet, particularly if opportunities to export power develop. Ontario Hydro needs to have recognized expertise to deal with these agencies effectively.

Ontario Hydro's acid rain monitoring program has facilitated the development of expertise and technical credibility. This in turn has made it possible to access, discuss and hopefully influence the work of others to the benefit of Ontario Hydro.

The general public expect that Ontario Hydro will conduct its operations in an environmentally sound manner. This includes studying the environmental impacts of emissions and keeping the amounts released within acceptable limits.

The acid rain monitoring program provided a concrete example of Ontario Hydro's commitment to the study of its impact on the environment.

The work was started when little was known about sulfate aerosol and acid rain and has lost some of its novelty. Public interests today are apt to be related to the impact of acid rain and plans to control emissions, the assumption being that acid rain exists and is related to acid gas emissions.

3.0 REVIEW OF ONGOING MONITORING ACTIVITIES

The main acid rain monitoring networks operating in Ontario and neighbouring regions were reviewed. Included were:

APN*	Air and Precipitation Network of Environment Canada
CANSAP*	Canadian Network for Sampling Acidic Precipitation of Environment Canada
APOS	Acidic Precipitation in Ontario Study of the Ontario Government
QUEBEC PPCN	Quebec Provincial Precipitation Chemistry Network
OH	Ontario Hydro's Air and Precipitation Monitoring Network
MAP3S/RAINE	Multistate Power Production Pollution Study/Regional Acidity of Industrial Emissions of the US-EPA and DOE
NADP	National Atmospheric Deposition Program of the US Department of Agriculture
UAPSP	Utility Acid Precipitation Study Program of the eastern US Utility Industry
WISCONSIN	Three-station network operated by the Wisconsin Utilities in cooperation with state agencies

Information obtained from the literature and through personal contact with the network operators is included in the Appendix. The most important findings are presented here.

Three types of networks were identified. The first two are daily or event networks in which wet deposition alone or wet deposition and air concentrations are being measured. The CANSAP component of CAPMON, MAP3S and UAPSP are of the first type, whereas the APN component of CAPMON, the event component of APOS and of course Ontario

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*The two Environment Canada networks are being combined and will, in the future, be known as

CAPMON	Canadian Acid Precipitation Monitoring Network

Hydro's network are of the second type. The third type is made up of cumulative networks which sample with a time resolution of a week to a month and includes the monthly component of APOS, NADP and the Government of Quebec network.

Sampling stations in Ontario and neighbouring regions are shown in Figures 1 and 2. The number of wet deposition stations in Ontario, excluding Ontario Hydro's stations, is about 66, of which 30 are or will shortly be event-type stations. Daily ambient concentrations are measured at 20 of these stations. The Quebec network has 46 weekly stations, while in the US, the NADP network consists of over 90 weekly stations and the MAP3S/RAINE, UAPSP and Wisconsin consist of 32 event-type stations.

4.0 DISCUSSION

Ontario Hydro's requirements for acid rain data were discussed in Section 2.0 and major ongoing monitoring activities were reviewed in Section 3.0. In this section we discuss the degree to which Ontario Hydro's requirements are met by the monitoring activities of other agencies.

The first set of needs discussed in Section 2.0 had to do with the contribution of Ontario Hydro's acidic gas emissions to acidic deposition. It was stated there that monitoring by itself will not generally provide information on Ontario Hydro's contribution to pollutant loadings in air and precipitation, except, perhaps where one is dealing with short range transport ($\sim$25 km) around a point source in a very clean environment. Consequently, models have had to be used to estimate the contribution of individual sources, such as Nanticoke TGS, to acidic deposition at, say, the Muskoka-Haliburton area some 250 km away. It should be noted, though, that present models are rather imprecise, having accuracies of a factor of 2 or 3 at best. Predictions based on such models are thus subject to large errors.

As stated in Section 2.0, most models available today are limited to long term (season/year) predictions of sulfur transport, transformation and deposition. These models need to be tested against observations so that adjustable model parameters can be fixed and the accuracy of the predictions can be assessed.

It would appear that the parameter selection and accuracy determination tasks can be done meaningfully only when a sufficient number of stations, measuring the various sulfur species in both air and precipitation with a time resolution comparable to that of the model (season), are available. Data from both cumulative and event networks are suitable. This being the case, then, the information in Figures 1 and 2 suggests that sufficient* wet deposition monitoring is being done in Ontario and neighbouring regions to satisfy Ontario Hydro's present modelling needs even if our network is terminated.

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*These are subjective judgments which attempt to take into consideration known gradients in concentration.

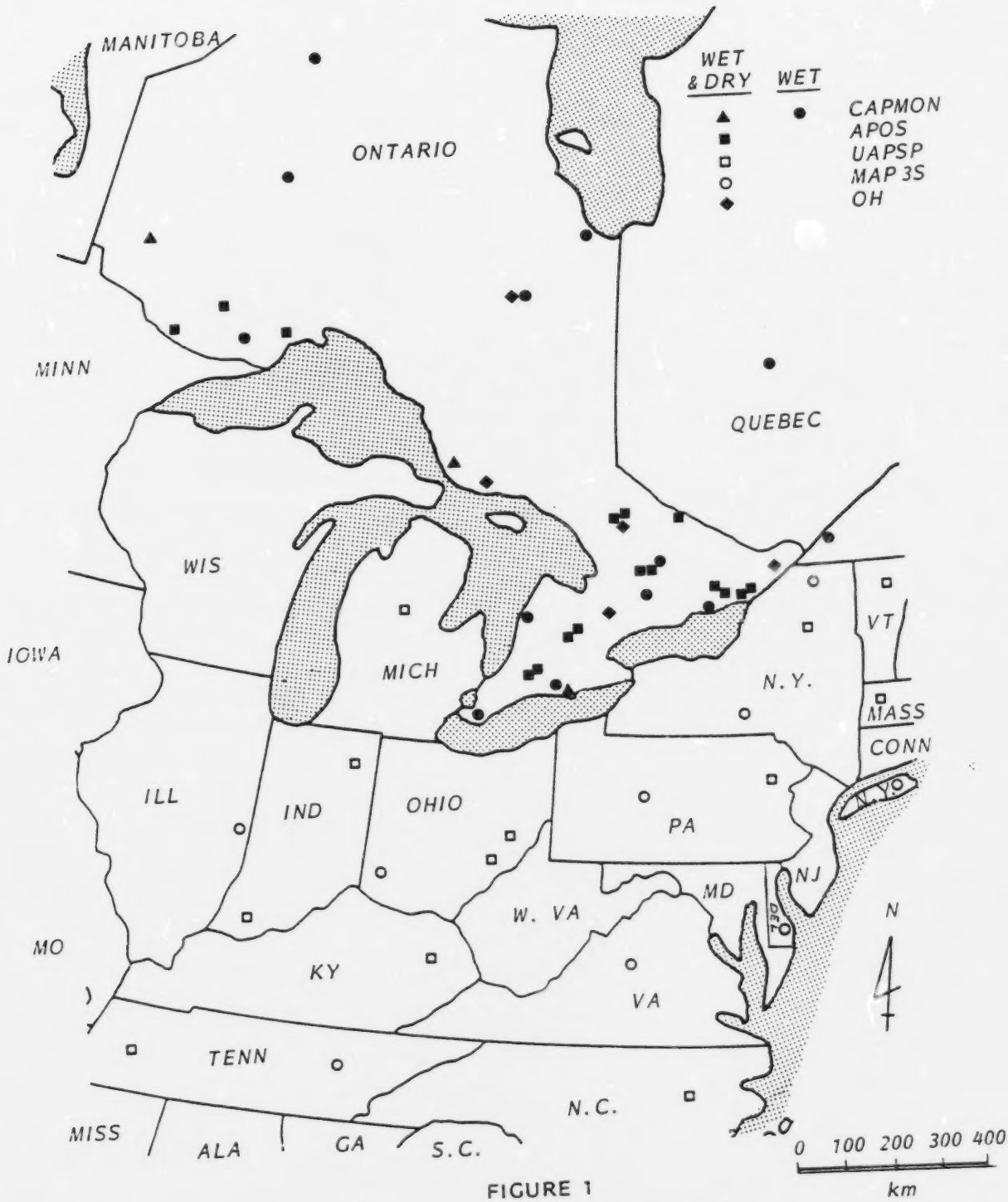

FIGURE 1

EVENT WET AND DRY ACIDIC DEPOSITION SAMPLING STATIONS
IN ONTARIO AND NEIGHBOURING REGIONS

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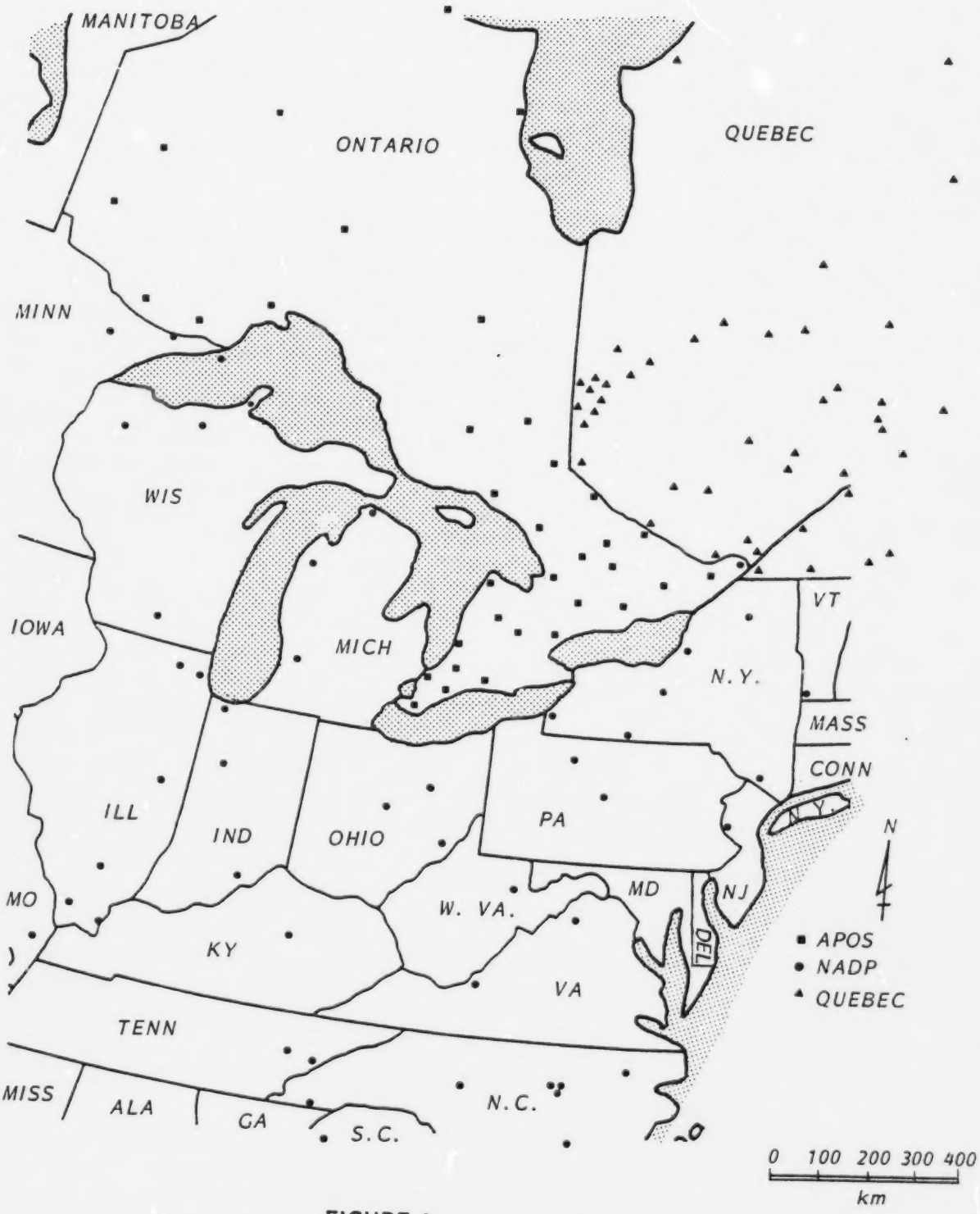

FIGURE 2

CUMULATIVE WET ACIDIC DEPOSITION SAMPLING STATIONS
IN ONTARIO AND NEIGHBOURING REGIONS

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Concentrations of acidic species in air are being measured at a relatively small number of sites, mainly in Ontario. The measured concentrations in air are used to estimate dry deposition by multiplying by an appropriately selected deposition velocity. The same approach is followed in models to arrive at dry deposition from calculated air concentrations. Comparison of measured and predicted air pollutant concentrations is thus a meaningful test of models and can be used to select model parameters. Removal of Ontario Hydro's stations will lead to an even poorer spatial coverage.

Future, improved models may be capable of handling all the chemical species which affect the acidity of precipitation and making predictions on an event basis. Application of such models will require event-type monitoring data. A marginally adequate* network of wet deposition stations is available in Ontario and neighbouring regions even if Ontario Hydro's stations are terminated, see Figure 1. Event-type stations monitoring concentrations of acidic species in air are the same ones mentioned in the previous paragraph and the same comments regarding poor spatial coverage with and without Ontario Hydro's stations apply.

The local contribution of a point source located in a relatively clean environment can be estimated from a dense ($\sim$10-30) network of samplers operating with a time resolution of a day or better. A study of this type may be possible at Atikokan TGS, depending on the capacity factor of this plant. However, the possibility of such a study has no bearing on what is done with the present monitoring network and so will not be discussed further.

As mentioned in Section 2.0, the important properties of acidic deposition may be determined by studying monitoring data. This can yield information on (a) long term trends in concentrations and their relationship to trends in emissions, (b) relative importance of wet and dry deposition and sulfur and nitrogen acidity, (c) geographical distribution and seasonal trends of concentrations and deposition, (d) relationship between air and precipitation concentrations, and (e) probable sources of precursors responsible for the acidity. Some of these investigations (eg, a,b and c) can be done with cumulative-type data, whereas others (eg, d and e) require event-type data. These studies are considered very worthwhile and will no doubt lead to a better understanding of the acid rain phenomenon. This reasoning forms the basis for a proposal from Ontario Hydro Research Division to the Federal Department of Supply and Services (DSS) in which studies of the type mentioned here would be carried out on a data set which included two additional years of operation of Ontario Hydro's network. Ontario Hydro Research Division plans to carry out a more modest interpretative study of data from the three event-type networks operating in Ontario up to May 31, 1983 if the proposal to DSS is not approved.

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*These are subjective judgments which attempt to take into consideration known gradients in concentration.

Data interpretation of the type mentioned above offers an alternate means by which Ontario Hydro can maintain technical expertise and at the same time contribute to the overall effort to understand acid rain.

It is apparent, then, that the monitoring network is not essential to maintain technical expertise and contribute to the study of acid rain. In fact, there appears to be an imbalance in scientific effort favouring monitoring over data interpretation. Application of our efforts toward data analysis is likely to make a bigger contribution than continuation of the present monitoring effort. Termination of the network, however, will make it more difficult for us to retain a good appreciation for the errors inherent in making acid rain measurements. This appreciation is essential in interpreting data.

As a point of interest, the cost of operating the network in 1982 amounted to $170,000 ($133,000 labour and $37,000 materials and expense). About 20% of the cost was associated with non-routine activities such as changes to the data screening and reporting procedures and modifications to the air samplers. The routine operation of the survey requires about 2 man-years of technician time, 1/3 of a man-year of a professional's time and $25,000 of materials and expense.

Finally, as was stated in Section 1.0, the survey was initially set up because of concerns over the health effects of sulfate aerosols. The survey was later adapted to study acid rain. This report has dealt with the needs for continuing to study acid rain only. It may be found advisable to reconsider the need for aerosol (trace elements, particle loadings, etc) sampling in Ontario as a separate issue.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Ontario Hydro has several ongoing requirements for acid rain data. These requirements can generally be met by the monitoring programs of other agencies. It is, therefore, not essential to continue the present monitoring program beyond the scheduled termination date of May 31, 1983. This conclusion is arrived at with the full recognition that the spatial coverage of event-type samplers, particularly air samplers, is marginally adequate even with Ontario Hydro's samplers in place.

Technical expertise will continue to be required for dealings with regulatory and other agencies over issues such as export licence applications. As well, the public will continue to view Ontario Hydro as a significant source of acidic gas emissions and expect Hydro to contribute to the study of acid rain. Interpretation of available acid rain data is not receiving as much attention as it deserves. Studies in this area provide an excellent opportunity to maintain expertise, and contribute to the study of acid rain. Such studies should continue at a modest level of effort.

These conclusions and recommendations were endorsed by ECC-A. Management approval should be sought and outside agencies need to be informed.

Termination of the network will free six dichotomous aerosol samplers for other applications. Discussions have been initiated with Thermal Generation Division about the possibility of deploying some of this equipment around operating thermal power plants to study trace element concentrations, particle loadings, etc.

ACKNOWLEDGEMENT

The other two members of the working group, Mr. J. Reeves of Thermal Generation Division and Dr. A. Torrenueva of Design and Development Division contributed to the preparation of this report. The members of ECC-A provided helpful comments on a previous draft of the working group report.

Approved:

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Submitted:

O.T. Melo
Supervising Engineer
Atmospheric Research Section

OTM/mf

APPENDIX

A summary of information gathered on the following networks

(APN)	Air and Precipitation Network of Environment Canada
(CANSAP)	Canadian Network for Sampling Acidic Precipitation of Environment Canada
CAPMON	Canadian Acid Precipitation Monitoring Network of Environment Canada consisting of APN and CANSAP
APOS	Acidic Precipitation in Ontario Study of the Ontario Government
QUEBEC PPCN	Quebec Provincial Precipitation Chemistry Network of the Government of Quebec
OH	Ontario Hydro's Acid Rain Network
MAP3S/RAINE	Multistate Power Production Pollution Study/Regional Acidity of Industrial Emissions of the US-EPA and DOE
NADP	National Atmospheric Deposition Program of the US Department of Agriculture
UAPSP	Utility Acid Precipitation Study Program of the eastern US Utility Industry
WISCONSIN	Three-station network operated by the Wisconsin Utilities in cooperation with state agencies

is contained in Tables A1 and A2 and Figures A1 to A9.

TABLE A1

SUMMARY OF INFORMATION ON SOME CANADIAN ACID RAIN SAMPLING NETWORKS

ACTIVITY	Network				
	APN	CANSAP	APOS	QUEBEC PTCN	OH
Current Monitoring	7 sites in Eastern Canada sampling precipitation and air concentrations on daily basis	45 sites in Canada sampling precipitation on a monthly basis	36 cumulative and 16 event sampling sites in Ontario. Event sites sample both precipitation and air.	46 sites in Quebec sampling precipitation on a weekly basis	5 sites in Ontario sampling precipitation and air concentrations on an event basis
Purpose	Fill gaps in understanding of the atmospheric cycles of acid-related substances. This required dry and wet deposition measurements with a time resolution of one day	Determine spatial distribution and temporal trend of wet deposition of acid-related substances in Canada	Determine long-term spatial distributions and trends across the Province. Study source contribution to acidic deposition and air pollutant concentrations. Estimate dry deposition on an event and cumulative basis	Determine levels and sources of precipitation constituents	Investigate the nature of acid rain by considering the ratio of wet to dry deposition, relationships between air and precipitation pollutant concentrations, importance of sulfur and nitrogen acidity, influence of transport direction, synoptic situation, etc
Duration	Established in 1978. Ongoing (at least 1988)	Established in 1977. Ongoing (at least 1988)	Established in 1980. Ongoing	Established in 1982. Ongoing	Established in 1975. Scheduled for termination on May 31, 1983
Future Plans	May extend coverage to Western Canada	Stations in Eastern Canada are being converted to daily sampling and resited where necessary. Western Canadian stations will be done later	Emphasize quality assurance		Survey may be extended for 2 years if full funding is obtained from DSS

TABLE A2

SUMMARY OF INFORMATION ON SOME USA ACID RAIN SAMPLING NETWORKS

Activity Description	Network			
	MAP3S/RAINE	NADP	UAPSP	WISCONSIN
Current Monitoring	9 sites in Eastern US sampling precipitation on daily basis	∿90 sites in US sampling wet and 'dry' precipitation on weekly basis	20 sites sampling precipitation in the eastern US on an event basis	3 sites sampling precipitation in Wisconsin on an event basis. 1 site samples air pollutant concentrations
Purpose	Evaluate trends and mechanisms of formation. Assess effects. Identify source of pollutants through trajectory analysis	Evaluate trends and geographical distribution. Address effects on agriculture, forest, rangelands and fresh water streams and lakes	Characterize chemical nature of precipitation. Identify spatial and temporal variations and long term trends. Identify effect of orography and large bodies of water. Identify relationships between atmospheric chemistry and precipitation chemistry. Identify effects of thunderstorm frequency and precipitation efficiency	Watershed study; trajectory study to identify effects of source regions
Duration	Established in 1976. Ongoing	Established in 1978. Ongoing	November 1981. Ongoing until March, 1984.	February, 1982. Ongoing until March, 1984.
Future Plans			Discussing extension beyond 1984. Inviting bids for data analysis	State agencies participating. Want to see extension beyond 1984.

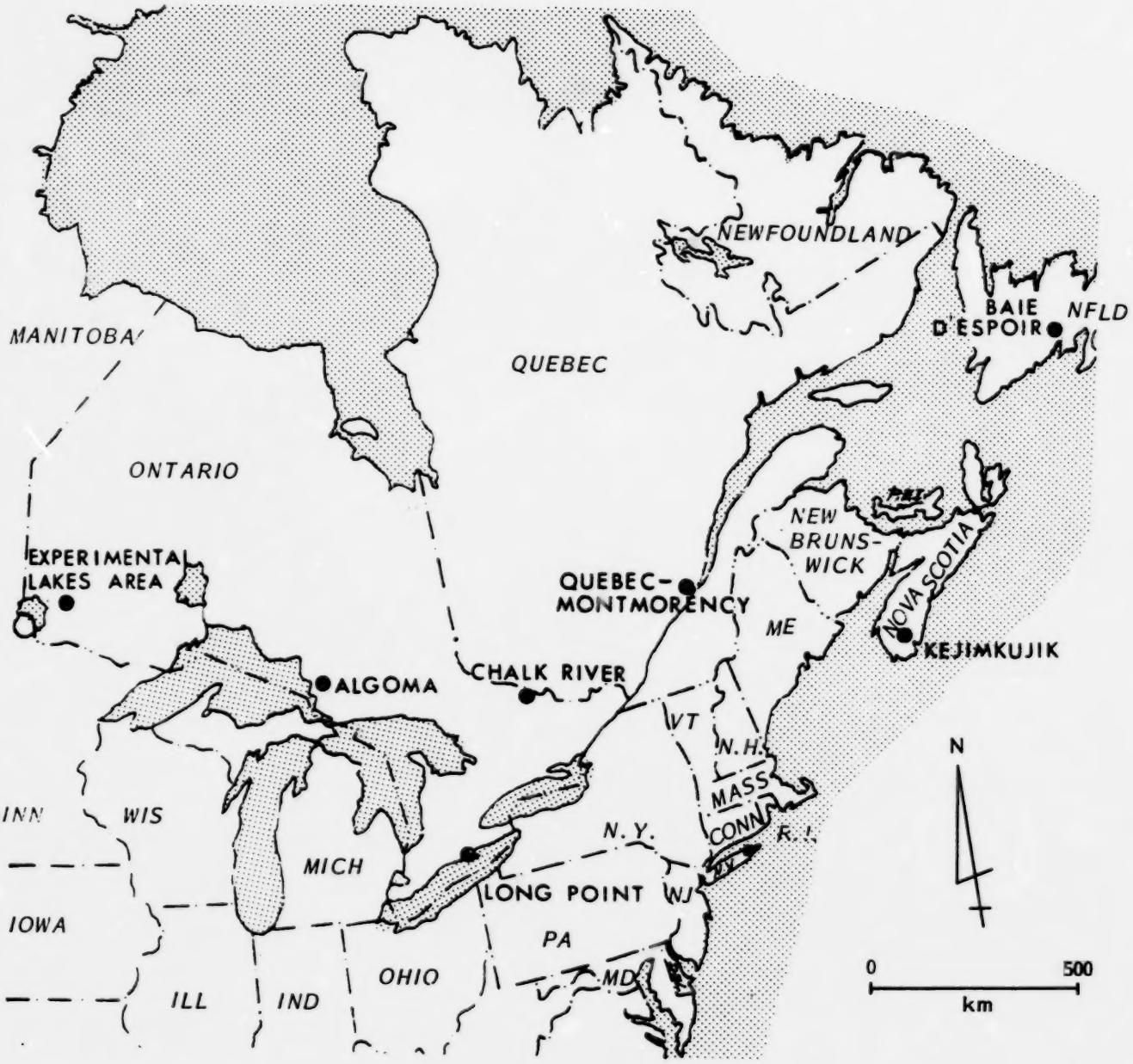

FIGURE A1
APN NETWORK

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FIGURE A2

CANSAP NETWORK

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FIGURE A3
APOS-EVENT NETWORK

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FIGURE A4
APOS CUMULATIVE NETWORK

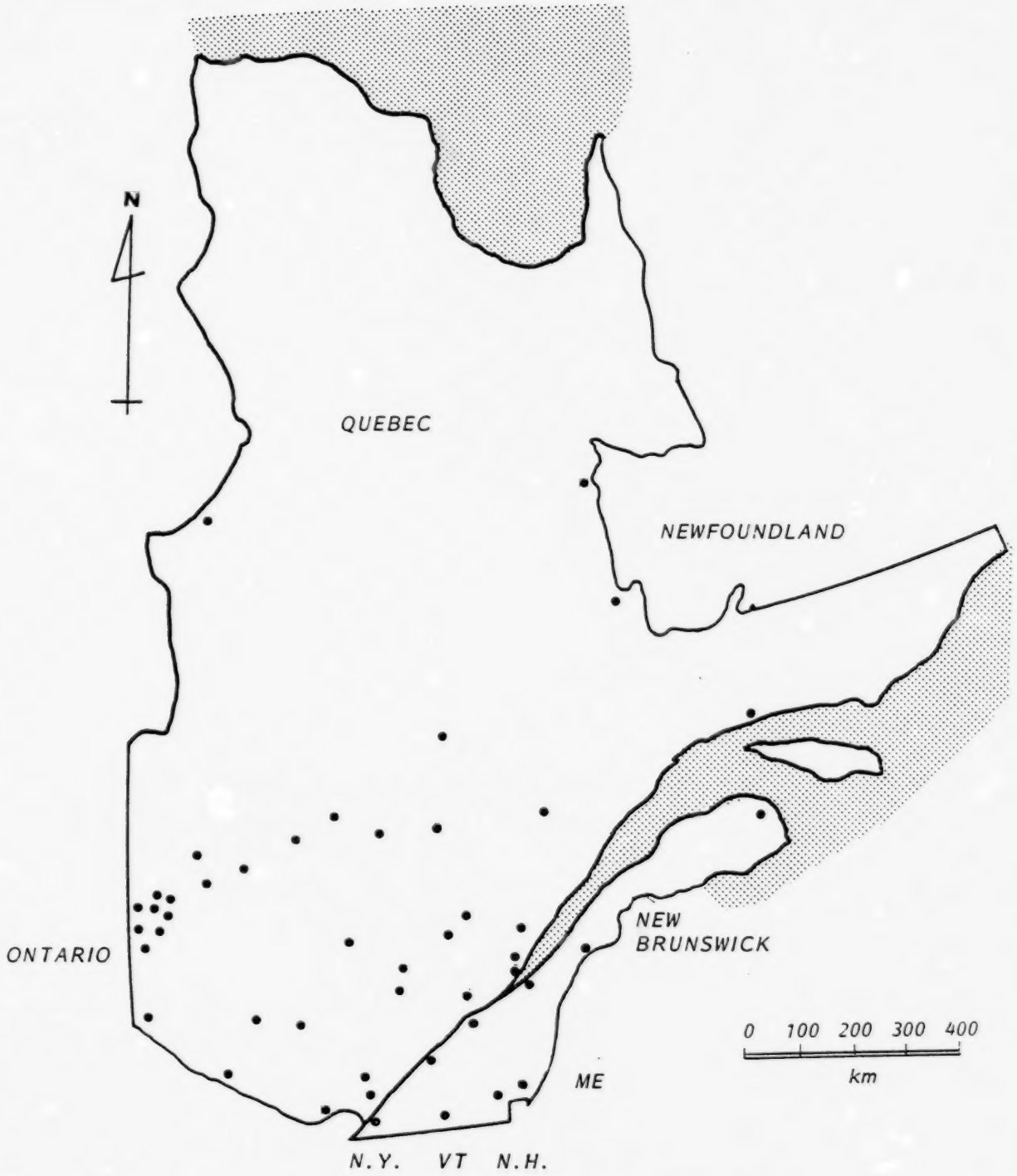

FIGURE A5
QUEBEC PROVINCIAL NETWORK

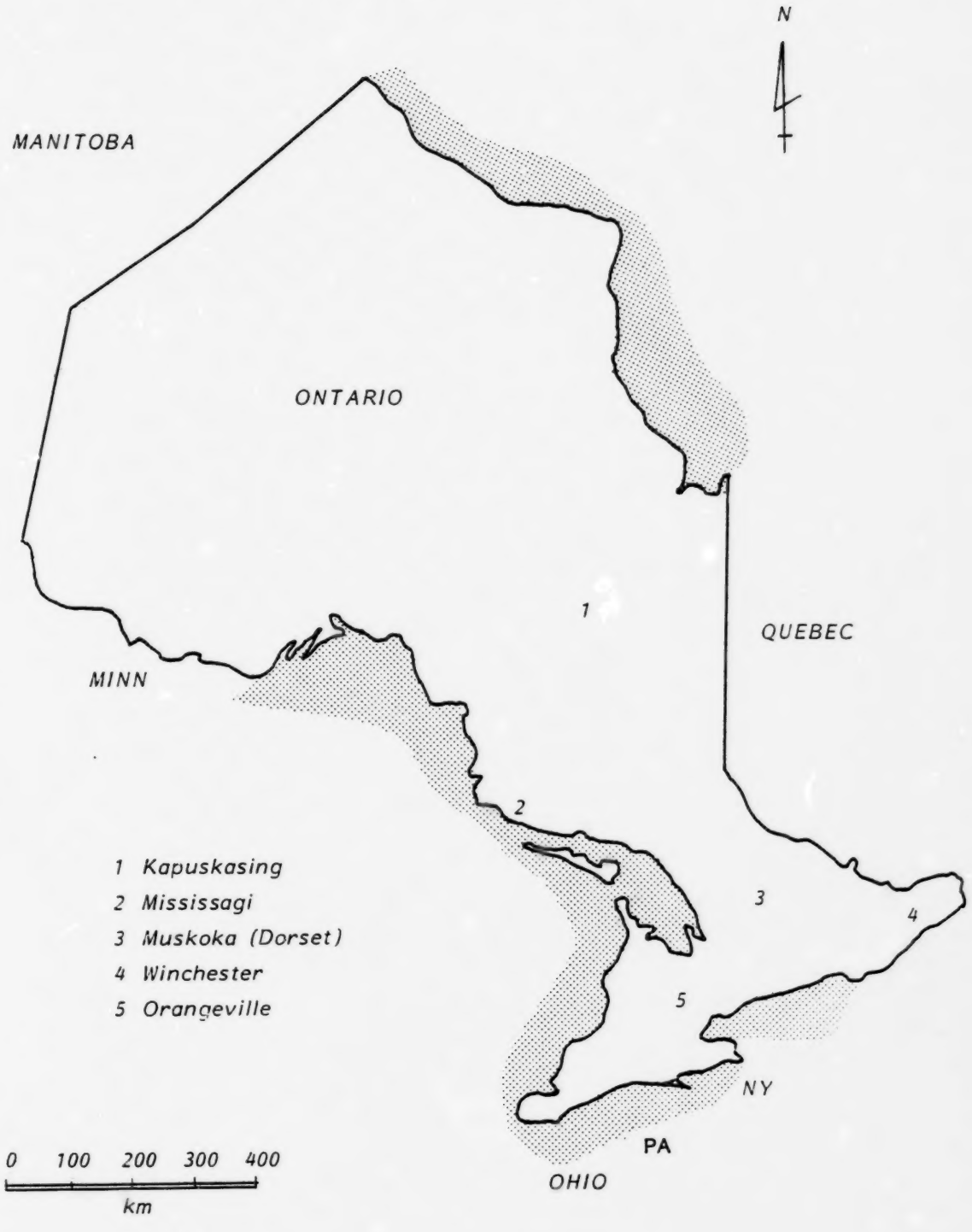

FIGURE A6
ONTARIO HYDRO NETWORK

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FIGURE A7
MAP 3S/RAINE NETWORK

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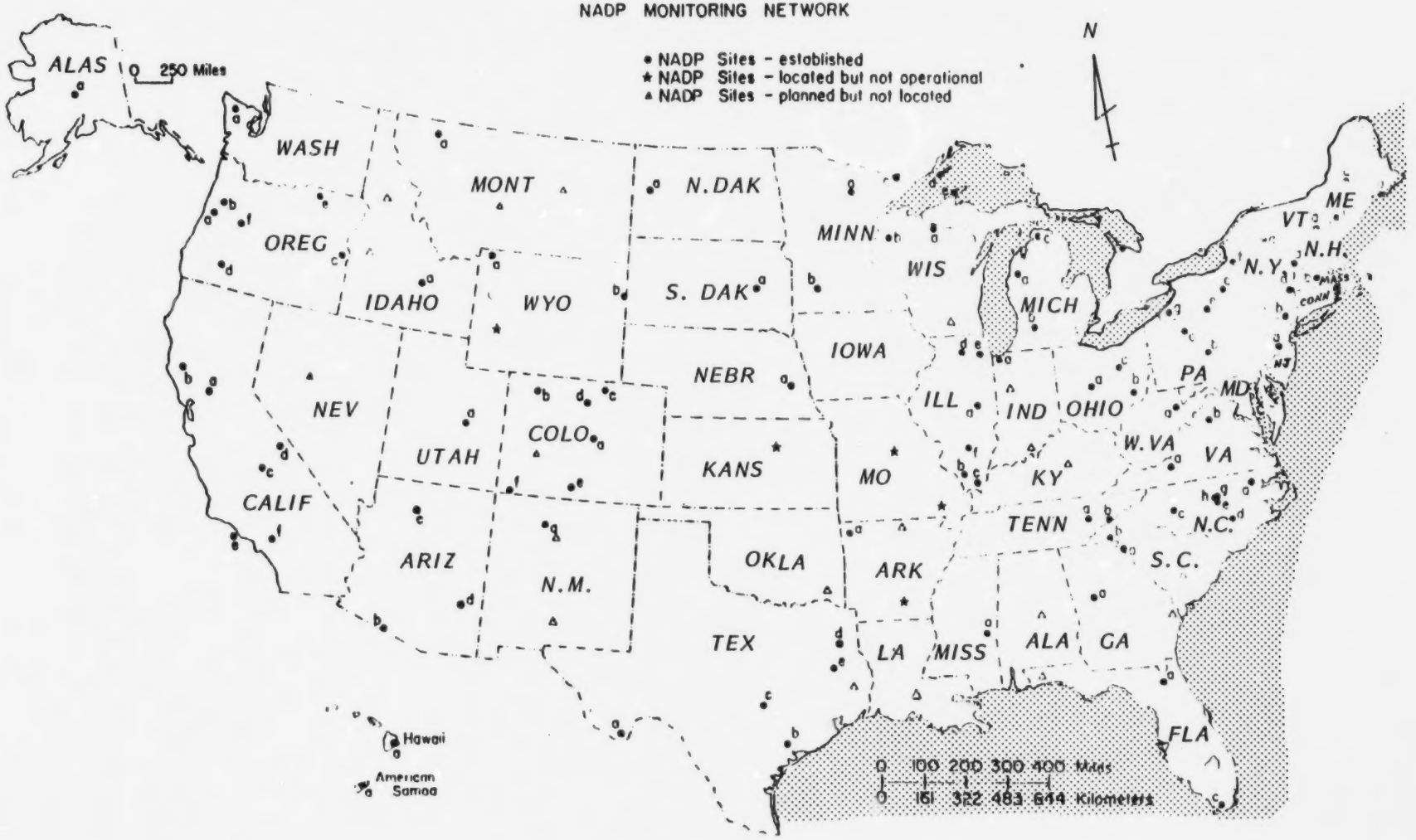

FIGURE A8
NADP NETWORK

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FIGURE A9

UAPSP AND WISCONSIN NETWORKS

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POOR

QUALITY

ORIGINAL